

A Survey of the Terrestrial Vertebrate Fauna of the Menindee Lakes, Western New South Wales

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ABSTRACT

The Menindee Lakes system in the Darling Riverine Plains bioregion in western New South Wales supports a diverse terrestrial vertebrate fauna. A survey of this fauna in spring 2000 and summer 2001 for the New South Wales Department of Land and Water Conservation revealed 12 mammal families (representing 25 species), 60 families of birds (164 species), eight reptile families (39 species), and two families of frogs (at least 7 species). Several new vertebrate species for the area were recorded, including the Stripe-faced Dunnart *Sminthopsis macroura*, Regent Parrot *Polytelis anthopeplus* and Woodland Blind Snake *Ramphotyphlops proximus*. Including historical records, the Menindee Lakes supports at least 305 terrestrial vertebrate species, including 18 species that are considered officially threatened in an international, national, or state context. At least another 18 terrestrial species are considered threatened regionally. Eight bird species are also protected under international agreements (JAMBA and CAMBA). The amount of woodlands in the region is relatively small, typically restricted to floodplains and the periphery of lakes, and usually dominated by either Black Box *Eucalyptus largiflorens* or River Red Gum *E. camaldulensis*. These woodlands, particularly the Black Box-dominated communities, were found to support relatively high numbers of terrestrial species because the Lower Darling River, its lakes and floodplains, provide resource-rich habitats in an otherwise resource-poor landscape.

Key words: Australia, birds, conservation status, Darling Riverine Plains bioregion, frogs, habitat fragmentation, local extinction, mammals, reptiles, species richness, terrestrial vertebrates

Introduction

The Menindee Lakes Storage Scheme, comprising a series of large ephemeral lakes as well as sections of the Darling River and the Great Darling Anabranch, is located in the hot, semi-arid environment of the Darling Riverine Plains bioregion in western New South Wales and is approximately 100km south-east of the township of Broken Hill (31° 58' S 141° 27' E) (Fig. 1). The Darling River is the longest tributary of the Murray River, and drains a substantial catchment of approximately 650,000 km², which takes in the Northern Tablelands of NSW and the Darling Downs of south-eastern Queensland (King and Green 1993).

The Menindee Lakes system covers an area of approximately 45,000 ha (Scholz *et al.* 1999) and consists of eight major lakes. The 'upper lakes' comprise the

northern ephemeral lakes of Malta (maximum area >380 ha), Bijiie (>1050 ha), Balaka (>1300 ha) and Tandure (2,100 ha) combined with the impounded section of the Darling River (Lake Wetherell). The 'lower lakes' include Lakes Cawndilla (9,440 ha), Menindee (15,900 ha) and Pamamaroo (6,940 ha) and exhibit a physiognomy more influenced by aeolian processes and therefore generally possess a higher proportion of low and more open shrublands. Three other small lakes, Spectacle Lake (adjacent to Lake Cawndilla), Speculation Lake (adjacent to Lake Menindee) and Eurobilli or Skeleton Lake (adjacent to Cawndilla Creek between Menindee and Cawndilla Lakes), are also part of this system.

The Menindee Lakes Storage Scheme was completed in 1968. The purpose of the scheme was to store and conserve flows in the Darling River and to secure water

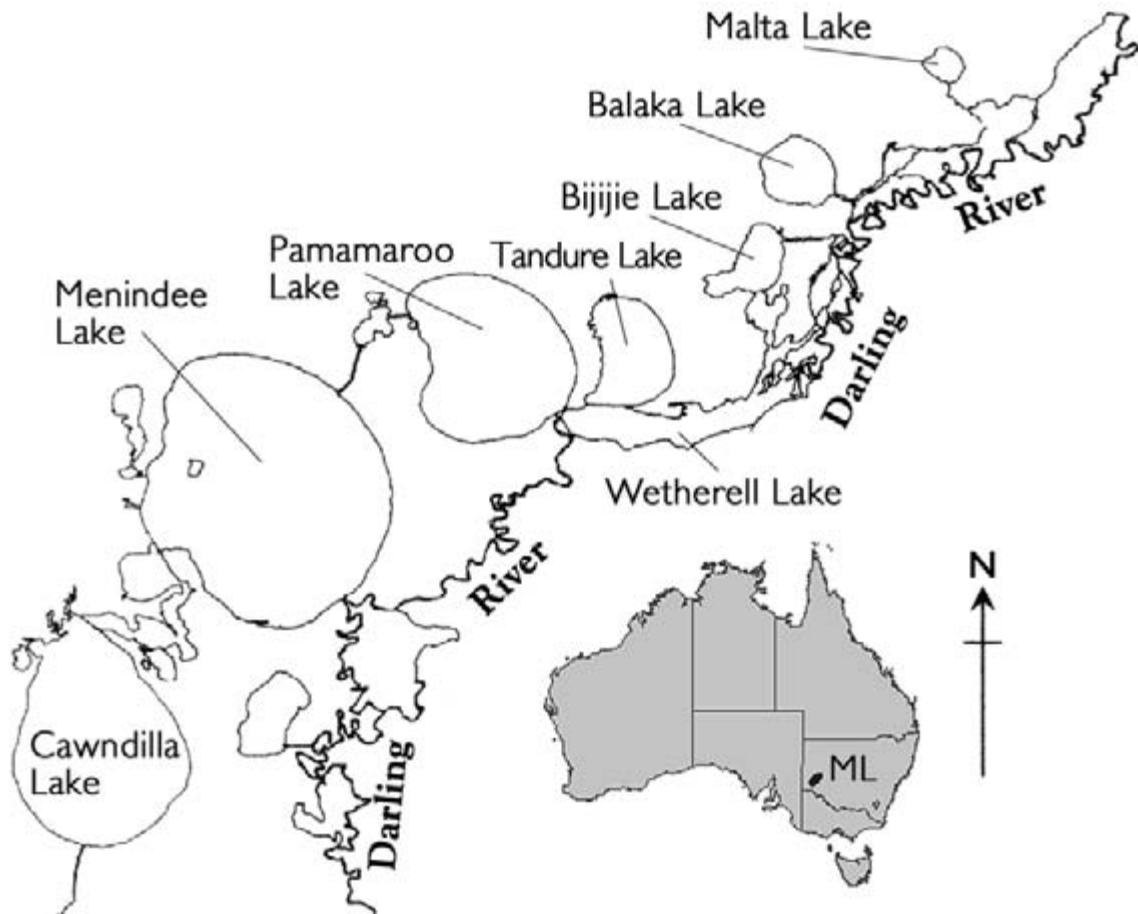


Figure 1 The Menindee Lakes system in south-western New South Wales, Australia.

to supply Broken Hill, Menindee and other settlements in the region. The Menindee Lakes Storage Scheme can also play a flood-mitigating role downstream of the lakes by pre-releasing water from the storage prior to the arrival of the flood. In addition, the lakes are important culturally (particularly for indigenous Australians) and are now a focus for recreation and regional tourism and are important for local and regional economies as a social resource (DLWC 1996, Thoms *et al.* 2000).

Prior to the construction of the Menindee Lakes Storage Scheme, the Menindee Lakes consisted of large open depressions on the Darling River floodplain. Each larger lake was connected separately to the river, with the exception of Lake Cawndilla which is connected to Menindee Lake by Cawndilla Creek. During floods, water flowed from the Darling River into the lakes, either filling or partially filling each lake and then drained back to the river during the flood recession, leaving residual pools in each of the lakes that gradually evaporated (DLWC 1996). The time that water remained in an individual lake depended on the depth of the lake. Lakes that flood intermittently are an important feature of semi-arid landscapes. The native flora and fauna of the region have adapted to this natural filling and drying regime of the lakes (Mussared 1997). This alternation between an aquatic and terrestrial environment has resulted in a high level of biodiversity (Read 1994, Thoms *et al.* 2000).

The Great Darling Anabranch is the parent river of the Darling River, which is much younger and formed only 11,000 years ago. The floodplain of the Darling is relatively

narrow and the river has low sinuosity, with small meanders in some sections while in others it is relatively straight. There are numerous billabongs adjacent to the river channel as well as some low-lying areas that support dense stands of *Lignum Muehlenbeckia florulenta*.

In contrast, the floodplain of the Anabranch is at times very wide and the river channel is sinuous with large meanders and several large ephemeral lakes. Billabongs, backwaters, saline lakes, Lignum swamps, and deep pools are also features of the Anabranch. Under natural conditions, the shallow and extensive nature of the Anabranch lakes and high evaporation rates ensured that none retained water on a permanent basis, although the largest of the lakes may have retained water for up to 5 years. The Anabranch was an ephemeral system that was normally dry with significant flows only occurring during periods of high flows and floods in the Darling River (King and Green 1993, Thoms *et al.* 2000). The water supply of the Anabranch is now a series of semi-permanent pools with relatively constant levels other than at times of medium and major floods (DLWC 1996).

While other parts of western New South Wales have been the target of intensive or extensive terrestrial fauna surveys (e.g. Tidemann 1988, Sadler and Shea 1989, Read 1994, Mazzer *et al.* 1998, Briggs *et al.* 2000, Shelly 2000, Webster *et al.* in press), the Menindee Lakes area has essentially experienced localised fauna surveys, primarily in Kinchega National Park (e.g. Everleigh 1978, Ellis and Henle 1988, Henle 1989), which covers 44,182 ha and embraces Lakes

Menindee and Cawndilla (NPWS, 1999). Until now, no terrestrial fauna survey has covered the entire Menindee Lakes system from Lake Malta downstream to the upper reaches of the Great Darling Anabranch.

The major objective of this study was to collect information on the occurrence and distribution of the vertebrate fauna of the Menindee Lakes system. This information, in combination with historical information, will assist in the evaluation of potential impacts of modifying the operation of the Lakes so as to improve water quality or reduce water losses, which in turn could be used for additional development or environmental purposes. It will also inform the historical change in the faunal composition of the region — the Western Division of New South Wales is known to have lost a number of vertebrate species, especially mammals, since first settlement (Lunney 2001).

Methods

Survey Sites

This survey of the terrestrial fauna was conducted at a range of sites around the major Menindee Lakes. Twenty sites were pre-determined by the New South Wales Department of Land and Water Conservation (DLWC) to ensure an even distribution of sites around the lakes and include a range of vegetation communities with obvious exposure to altered water management regimes. It was not the objective to stratify study sites across all communities occurring in the study area, but to focus on those communities typically situated near water-bodies, and therefore most susceptible to inundation or watertable influence.

To better represent targeted communities (for birds and herpetofauna), this study established 55 supplementary sites — 51 for diurnal bird census and four for herpetofaunal census — thereby adding two frequently-inundated vegetation communities (River Red Gum *Eucalyptus camaldulensis* Forest/Woodland and Lignum Swamp) to the investigation. However, some communities in the study area are not directly exposed to the influence of hydrological change and remained unsampled (e.g. Belah Woodland *Casuarina cristata*).

The focus of this survey was predominantly on the lake margins where, often, the different vegetation (or habitat) 'types' consist of narrow bands, most graphically exemplified by the Black Box and River Red Gum communities. A consequence of this restricted distribution of the vegetation is the existence of ecological ecotones (interfaces), and this necessitated the recognition of multiple habitats at many sites, although for simplicity the spatially dominant community across the sampling area is used as the 'habitat' type in this paper. This mixture of habitats at some sites also explains why some animal species in this study, typically resident within a well-defined vegetation community, have been recorded in an adjacent (and atypical) community. For example, the Crimson Chat *Epthianura tricolor* typically is a species of open shrublands and while most frequently recorded in Low Open Chenopod Shrubland, it was also recorded from sites in Black Box Woodlands that abutted shrubland.

Survey Techniques

Each of the survey sites was surveyed in spring 2000 and again in summer 2001, considered the optimum seasons for fauna survey given the financial and time constraints. The two field-trips in each season were conducted within a six-week period to reduce any seasonal variability between sampling within the one season. The spring surveys were conducted between late September and early November (when most summer migrants are known to be present) and the summer surveys in January and February (when some additional species could appear in response to drying conditions further inland).

Fauna survey techniques followed the New South Wales National Parks and Wildlife Service (NPWS) sampling protocols and included the following: diurnal bird census, pitfall trapping, Elliott trapping, hair analysis (hair-tube sampling), call-playback (for frogs and nocturnal birds), herpetofauna searches (both diurnal and nocturnal), and harp-trapping and Anabat (ultrasonic) recording for bats. Incidental records of species were also collected from sightings of individuals or other identifiable signs (e.g. tracks, scats, feathers, reptile slough). Details of each sampling technique are provided in Appendix 1.

While the focus of this study was terrestrial vertebrates, records of waterbirds were also collected where relevant. Waterbirds are defined as those species dependent on wetlands for their survival and include those species dependent on muddy shores, the aquatic and emergent vegetation of wetlands and the vegetation of frequently inundated depression of their margins. Waterbirds were the subject of a separate study not reported here. This paper concentrates on the birds of terrestrial systems (i.e. 'bush birds') in the Menindee Lakes area.

Nomenclature in this paper follows Menkhurst and Knight (2001) for mammals, Christidis and Boles (1994) for birds, and Cogger (2000) for reptiles and frogs, unless otherwise indicated.

Vegetation

The vegetation within the Menindee Lakes system is diverse, providing an array of available habitats from open semi-arid plains with shrublands and woodlands to ephemeral lakes and swamps. The vegetation is dominated by Black Box Woodlands, which occupy much of the floodplains of the Darling River and the Great Darling Anabranch. Associated with these woodlands are the River Red Gum Forest/Woodlands and a complex system of ephemeral wetlands, swamps, lakes and billabongs. The Red Gum Forest/Woodlands occupy areas subject to more frequent and prolonged flooding than the Black Box Woodlands and are often restricted to narrow bands which line the major channels and billabongs and the fringes of the now semi-permanent lakes formed by the Menindee Lakes Storage Scheme (University of Ballarat 1999).

It is important to distinguish the lake fringe Black Box communities in the Menindee area as they have been largely destroyed by the now permanent flooding of many of the lakes within the system. In most cases only

the very outer edge of the original community remains, which is often an ecotone between the lake-influenced communities and communities of the surrounding plains.

Away from the inundated areas the major communities are the Belah/Rosewood *Alectryon oleifolius* Woodlands which occupy the extensive linear dunefields, particularly common to the south and east of Poongahie, and the Chenopod Shrublands which occur on the sand-plains. These shrublands are usually dominated by Bluebush and Pearlbush (both *Maireana*) and *Atriplex* species (University of Ballarat 1999).

The habitat classification used in this survey is a broad structural classification based on the density and height of tree, shrub or ground layer with reference to the dominant species in defining layers (and adapted from that developed by Biosis Research Pty Ltd). Although the focus of this study was the fauna of terrestrial communities, represented by six major habitat types, descriptions for all broad habitat types used during the survey (including swamps, marshes and open water) are described in brief in Appendix 2.

Limitations of this study

The study focused on terrestrial communities close to the Menindee Lakes, and there is little doubt that more species could have been found if more time had been spent in aquatic or arid habitats. The number of study sites was particularly small for all terrestrial fauna but birds, and these sites were concentrated in Black Box Woodland. The study was conducted in two seasons only, and during exceedingly hot conditions in summer — during February the region experienced extended periods of extremely hot weather necessitating some censusing in abnormally high temperatures. Temperature, wind speed and time of day are known to influence the activity, vocalisation and therefore the detectability of birds (Hewish and Loyn 1989, Slater 1994). Thirdly, the study was conducted while lake-levels were atypically high, preventing the examination of habitats that are intermittently inundated. Many of the study sites were located on ecotones, and some records could not be assigned readily to a single habitat.

Results

Fauna of the Menindee Lakes

Combining historical records with the 2000-01 survey records reveals that at least 305 terrestrial vertebrate species are known from the Menindee Lakes area, comprising 34 mammal, 206 bird, 56 reptile and 9 frog species. Historical records, derived from a number of large institutional data-bases (see acknowledgements), were accumulated for the 1:100,000 topographic maps that cover the 'northern' (ephemeral) lakes (Natmap Menindee 7333) and the 'southern' (permanent) lakes (Nartooka 7433). While many of these species were recorded during the 2000-01 survey, a large proportion has not been recorded from the area for some time.

Survey Records

At least 235 vertebrate species were recorded during this survey. The distribution of these species across the major habitat types is presented in Table 1, along with the methods of detection and the frequency of recording for each species, and the number of established survey sites at which they were recorded.

A few species (i.e. Red Kangaroo *Macropus rufus*, Western Grey Kangaroo *M. fuliginosus*, Rabbit *Oryctolagus cuniculus*, Stumpy-tailed Lizard *Trachydosaurus rugosus*) were considered so abundant and widespread in the study area that incidental observations of these species were not usually recorded. The House Mouse *Mus musculus* was commonly recorded from the majority of sites, particularly in spring when the species appeared to be in plague.

The number of species from each of the fauna groups that were recorded for the six main habitat types is shown in Table 2. Black Box Woodland supported the most species, although this would have been affected by the disproportionate amount of survey effort (in terms of numbers of sites) in this habitat type. Shrubland and Low Open Chenopod Shrubland also yielded relatively high numbers of species for each vertebrate group and overall, despite the lower survey effort.

Low Canegrass Shrubland on the shores of Lake Menindee produced the only record of Common Dunnart *Sminthopsis murina* for the survey area and a relatively rich herpetofaunal complement, including seven gecko species, relatively large numbers of Regal Striped Skink *Ctenotus regius* as well as the Short-tailed Snake *Suta nigriceps*, recorded only once during the survey. Two species of tree frog and three species of southern frogs, including the uncommonly recorded Trilling Frog *Neobatrachus centralis*, were found in various habitat types on the margins of this lake.

Mammals

Records of 25 species of mammals from 12 families were recorded during the survey (Table 1). These comprised Tachyglossidae (1 species), Dasyuridae (5), Phalangeridae (1), Macropodidae (2), Molossidae (2), Vespertilionidae (7), Muridae (2), Leporidae (1), Canidae (1), Felidae (1), Suidae (1), and Bovidae (2). The number of individuals recorded by ultrasonic bat detectors and hair tubes could not be determined, thus each species recorded by these techniques at a site was counted as a single record.

Nine species of bat were recorded across the standard survey sites (Table 1). Identification of species was based on the frequency and shape characteristics of echolocation calls when viewed with *Anabat 6* software. While many species produce some distinctive calls, there is considerable overlap between species with regard to the frequency and shape of pulses in the call repertoire. The calls of some species were distinctive and could generally be readily identified (e.g. White-striped Freetail Bat *Tadarida australis*). Conversely, some species overlapped considerably with other species in call type and could only be identified from a small proportion of their calls (e.g. Inland Broadnosed Bat

Table 1 Numbers of individual vertebrate species recorded by different survey methods for each habitat type during the Menindee Lakes fauna survey, 2000-01. The methods by which each species was recorded and their frequency of occurrence (no. of study sites) are also given. Superscript next to a common name denotes an introduced species

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
Mammals														
Short-beaked Echidna	<i>Tachyglossus aculeatus</i>	3	2	IO					✓					
Giles' Planigale	<i>Planigale gilesi</i>	10	7	PF		✓			✓					
Narrow-nosed Planigale	<i>Planigale tenuirostris</i>	4	1	PF					✓					
Unidentified <i>Planigale</i> sp.	<i>Planigale</i> sp.	-	1	HT					✓					
Fat-tailed Dunnart	<i>Sminthopsis crassicaudata</i>	7+	4	PF, HT		✓			✓					
Stripe-faced Dunnart	<i>Sminthopsis macroura</i>	1	1	PF					✓					
Common Dunnart	<i>Sminthopsis murina</i>	1	1	PF					✓					
Common Brushtail Possum	<i>Trichosurus vulpecula</i>	-	3	HT		✓			✓					
Western Grey Kangaroo	<i>Macropus fuliginosus</i>	20	8	IO	✓	✓	✓	✓	✓					
Red Kangaroo	<i>Macropus rufus</i>	9	5	IO	✓	✓			✓					
Water Rat	<i>Hydromys chrysogaster</i>	-	1	HT					✓					
House Mouse ^e	<i>Mus musculus</i>	124	17	HT, PF	✓	✓	✓	✓	✓					
Rabbit ^t	<i>Oryctolagus cuniculus</i>	7	7	IO	✓				✓	✓				
Pig ^l	<i>Sus scrofa</i>	23	11	IO		✓			✓	✓				
Goat ^t	<i>Capra hircus</i>	1	1	IO					✓					
Cat ^t	<i>Felis catus</i>	2	1	IO					✓					
Fox ^x	<i>Vulpes vulpes</i>	9	7	IO					✓					
Inland freetail bat	<i>Mormopterus</i> sp. small penis	8	4	H	✓				✓					
Unidentified <i>Mormopterus</i> sp.	<i>Mormopterus</i> sp.	8+	20	H, D	✓				✓					
White-striped Freetail Bat	<i>Tadarida australis</i>	-	9	D	✓	✓			✓					
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>	685+	20	H, D	✓	✓	✓	✓	✓					
Little Pied Bat	<i>Chalinolobus picatus</i>	11+	6	H, D		✓			✓					
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>	82	18	H	✓	✓	✓	✓	✓					
Inland Broadnosed Bat	<i>Scotorepens balstoni</i>	30+	10	H, D	✓	✓	✓	✓	✓					
Unidentified <i>Scotorepens</i> sp.	<i>Scotorepens balstoni</i> / <i>S. greyii</i>	44+	12	H, D	✓	✓	✓	✓	✓					
Little Broadnosed Bat	<i>Scotorepens greyii</i>	310+	19	H, D	✓	✓	✓	✓	✓					
Inland Forest Bat	<i>Vespadelus baverstocki</i>	2	3	H, D	✓			✓	✓					
Unidentified <i>Vespadelus</i> sp.	<i>Vespadelus baverstocki</i> / <i>V. vulturnus</i>	12+	4	H, D				✓						
Little Forest Bat	<i>Vespadelus vulturnus</i>	137	20	H, D	✓	✓	✓	✓	✓					
Birds														
Emu	<i>Dromaius novaehollandiae</i>	25	11	DC	✓				✓	✓	✓			
Stubble Quail	<i>Coturnix novaeseelandiae</i>	1	0	IO		✓								
Brown Quail	<i>Coturnix ypsilophora</i>	1	0	IO		✓								
Little Button-quail	<i>Turnix velox</i>	3	0	IO	✓	✓			✓					
Peafowl	<i>Pavo cristatus</i>	2	1	DC, IO					✓					
Rock Dove	<i>Columba livia</i>	24	0	IO										✓
Peaceful Dove	<i>Geopelia striata</i>	448	61	DC, IO	✓	✓	✓	✓	✓	✓	✓			
Diamond Dove	<i>Geopelia cuneata</i>	112	33	DC, IO	✓	✓	✓	✓	✓	✓	✓			
Common Bronzewing	<i>Phaps chalcoptera</i>	53	25	DC, IO	✓				✓	✓				
Crested Pigeon	<i>Ocyphaps lophotes</i>	360	57	DC, IO	✓	✓	✓	✓	✓	✓	✓			
Australian Spotted Crake	<i>Porzana fluminea</i>	2	1	DC, IO							✓	✓		

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
Black-tailed Native-hen	<i>Gallinula ventralis</i>	294	9	DC, IO				✓	✓	✓	✓	✓	✓	
Dusky Moorhen	<i>Gallinula tenebrosa</i>	5	0	IO								✓		
Purple Swampphen	<i>Porphyrio porphyrio</i>	11	2	DC, IO				✓		✓	✓			
Eurasian Coot	<i>Fulica atra</i>	2	1	DC				✓						
Great Crested Grebe	<i>Podiceps cristatus</i>	4	1	DC, IO				✓						✓
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	9	0	IO							✓			
Great Cormorant	<i>Phalacrocorax carbo</i>	203	9	DC, IO		✓	✓	✓	✓		✓			✓
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>	60	6	DC, IO		✓		✓	✓	✓	✓			✓
Pied Cormorant	<i>Phalacrocorax varius</i>	121	20	DC, IO	✓	✓	✓	✓	✓		✓			✓
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>	4	2	DC, IO				✓			✓			✓
Darter	<i>Anhinga melanogaster</i>	17	8	DC, IO			✓	✓	✓	✓	✓			✓
Australian Pelican	<i>Pelecanus conspicillatus</i>	183	17	DC, IO	✓	✓		✓	✓		✓			✓
Whiskered Tern	<i>Chlidonias hybridus</i>	2	1	DC				✓						
Gull-billed Tern	<i>Sterna nilotica</i>	33	5	DC, IO	✓	✓		✓						✓
Caspian Tern	<i>Sterna caspia</i>	48	3	DC, IO	✓	✓	✓	✓						✓
Silver Gull	<i>Larus novaehollandiae</i>	59	12	DC, IO	✓	✓	✓	✓	✓		✓			✓
Red-kneed Dotterel	<i>Erythronyx cinctus</i>	2	1	DC, IO					✓					
Masked Lapwing	<i>Vanellus miles</i>	30	9	DC, IO	✓	✓		✓	✓		✓	✓	✓	
Black-fronted Dotterel	<i>Euseyonis melanops</i>	54	14	DC, IO				✓	✓	✓	✓			✓
Black-winged Stilt	<i>Himantopus himantopus</i>	29	2	DC, IO				✓	✓		✓			✓
Banded Stilt	<i>Himantopus leucocephalus</i>	1	0	IO	✓									
Red-necked Avocet	<i>Recurvirostra novaehollandiae</i>	13	0	IO										✓
Black-tailed Godwit	<i>Limosa limosa</i>	1	0	IO										✓
Common Sandpiper	<i>Actitis hypoleucos</i>	6	0	IO									✓	
Pectoral Sandpiper	<i>Calidris melanotos</i>	3	0	IO										✓
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	3	0	IO										✓
Australian Pratincole	<i>Stiltia isabella</i>	6	2	DC, IO		✓		✓						
Australian Bustard	<i>Ardeotis australis</i>	1	0	IO	✓									
Glossy Ibis	<i>Plegadis falcinellus</i>	1	0	IO							✓			
Australian White Ibis	<i>Threskiornis molucca</i>	22	6	DC, IO		✓		✓		✓	✓			✓
Straw-necked Ibis	<i>Threskiornis spinicollis</i>	14	2	DC, IO	✓				✓		✓	✓	✓	
Royal Spoonbill	<i>Platalea regia</i>	33	2	DC, IO				✓			✓			✓
Yellow-billed Spoonbill	<i>Platalea flavipes</i>	60	9	DC, IO		✓		✓	✓	✓	✓			✓
Little Egret	<i>Egretta garzetta</i>	5	4	DC, IO			✓	✓						
Intermediate Egret	<i>Ardea intermedia</i>	27	6	DC, IO				✓	✓		✓			✓
Great Egret	<i>Ardea alba</i>	33	14	DC, IO	✓			✓	✓	✓	✓			✓
White-faced Heron	<i>Egretta novaehollandiae</i>	58	19	DC, IO		✓		✓	✓	✓	✓			✓
White-necked Heron	<i>Ardea pacifica</i>	23	14	DC, IO	✓	✓		✓	✓	✓	✓			✓
Nankeen Night Heron	<i>Nycticorax caledonicus</i>	12	5	DC, IO		✓		✓	✓					✓
Australian Wood Duck	<i>Chenonetta jubata</i>	150	8	DC, IO				✓	✓	✓				✓
Black Swan	<i>Cygnus atratus</i>	129	6	DC, IO	✓	✓		✓			✓			✓
Australian Shelduck	<i>Tadorna tadornoides</i>	50	8	DC, IO	✓			✓	✓	✓	✓			✓
Pacific Black Duck	<i>Anas superciliosa</i>	76	5	DC, IO				✓	✓		✓			✓
Chestnut Teal	<i>Anas castanea</i>	9	1	DC, IO					✓		✓			✓
Grey Teal	<i>Anas gracilis</i>	220	11	DC, IO				✓	✓		✓	✓	✓	
Australasian Shoveler	<i>Anas rhynchotis</i>	15	1	DC, IO					✓		✓			✓

Menindee Lakes vertebrates

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
Pink-eared Duck	<i>Malacorhynchus membranaceus</i>	6	2	DC, IO				✓						✓
Hardhead	<i>Aythya australis</i>	12	0	IO				✓			✓			✓
Blue-billed Duck	<i>Oxyura australis</i>	1	0	IO							✓			
Swamp Harrier	<i>Circus approximans</i>	1	0	IO										✓
Brown Goshawk	<i>Accipiter fasciatus</i>	6	4	DC, IO		✓		✓	✓					
Collared Sparrowhawk	<i>Accipiter cirrhocephalus</i>	1	1	DC				✓						
Wedge-tailed Eagle	<i>Aquila audax</i>	25	11	DC, IO	✓	✓		✓		✓				
Little Eagle	<i>Hieraetus morphnoides</i>	3	2	DC, IO		✓		✓						
White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	2	1	DC					✓					
Whistling Kite	<i>Haliastur sphenurus</i>	86	43	DC, IO	✓	✓	✓	✓	✓	✓				
Black Kite	<i>Milvus migrans</i>	25	16	DC, IO	✓	✓	✓	✓	✓					
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>	5	3	DC				✓						
Black-shouldered Kite	<i>Elanus axillaris</i>	12	7	DC, IO	✓		✓	✓						
Australian Hobby	<i>Falco longipennis</i>	4	3	DC, IO			✓	✓	✓		✓			
Peregrine Falcon	<i>Falco peregrinus</i>	2	2	DC				✓						
Brown Falcon	<i>Falco berigora</i>	3	2	DC, IO	✓	✓			✓					
Nankeen Kestrel	<i>Falco cenchroides</i>	13	10	DC	✓	✓	✓	✓	✓					
Southern Boobook	<i>Ninox novaeseelandiae</i>	35	14	DC, NC		✓		✓	✓					
Barn Owl	<i>Tyto alba</i>	23	10	DC, QNC	✓	✓		✓	✓					
Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii</i>	172	1	DC, IO		✓		✓						
Major Mitchell's Cockatoo	<i>Cacatua leadbeateri</i>	6	1	DC, IO				✓						
Little Corella	<i>Cacatua sanguinea</i>	249	30	DC, IO	✓	✓	✓	✓	✓					
Galah	<i>Cacatua roseicapilla</i>	459	39	DC, IO	✓	✓	✓	✓	✓					
Cockatiel	<i>Nymphicus hollandicus</i>	93	12	DC, IO	✓	✓		✓		✓				
Regent Parrot	<i>Polytelis anthopeplus</i>	1	1	DC				✓						
Australian Ringneck	<i>Barnardius zonarius</i>	95	26	DC		✓		✓	✓	✓				
Red-rumped Parrot	<i>Psephotus haematonotus</i>	543	38	DC, IO	✓	✓		✓	✓	✓				
Mulga Parrot	<i>Psephotus varius</i>	21	5	DC, IO	✓	✓		✓						
Blue Bonnet	<i>Northiella haematogaster</i>	130	20	DC	✓	✓	✓	✓	✓	✓				
Blue-winged Parrot	<i>Neophema chrysostoma</i>	3	2	DC, IO	✓			✓						
Elegant Parrot	<i>Neophema elegans</i>	9	2	DC, IO	✓			✓						
Budgerigar	<i>Melopsittacus undulatus</i>	196	14	DC	✓	✓		✓		✓				
Tawny Frogmouth	<i>Podargus strigoides</i>	5	0	IO		✓		✓	✓					
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>	56	25	DC, QNC	✓	✓		✓	✓					
Laughing Kookaburra	<i>Dacelo novaeguineae</i>	21	10	DC				✓	✓					
Red-backed Kingfisher	<i>Todiramphus pyrrhopygia</i>	24	12	DC, IO	✓	✓	✓	✓	✓					
Sacred Kingfisher	<i>Todiramphus sanctus</i>	111	43	DC, IO	✓	✓	✓	✓	✓	✓				
Rainbow Bee-eater	<i>Merops ornatus</i>	217	43	DC, IO	✓	✓	✓	✓	✓					
White-throated Needletail	<i>Hirundapus caudacutus</i>	1	1	DC				✓						
Fork-tailed Swift	<i>Apus pacificus</i>	28	3	DC			✓	✓	✓					
Pallid Cuckoo	<i>Cuculus pallidus</i>	7	3	DC, IO	✓	✓		✓						
Black-eared Cuckoo	<i>Chrysococcyx osculans</i>	1	1	DC				✓						
Horsfield's Bronze-Cuckoo	<i>Chrysococcyx basalus</i>	50	31	DC	✓	✓	✓	✓	✓	✓				
Welcome Swallow	<i>Hirundo neoxena</i>	52	11	DC, IO		✓	✓	✓	✓	✓	✓			

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
White-backed Swallow	<i>Cheramoeca leucosternus</i>	42	10	DC, IO		✓	✓	✓					✓	✓
Tree Martin	<i>Hirundo nigricans</i>	1016	47	DC, IO	✓	✓	✓	✓	✓	✓	✓			
Fairy Martin	<i>Hirundo ariel</i>	17	6	DC, IO		✓		✓	✓				✓	
Willie Wagtail	<i>Rhipidura leucophrys</i>	338	62	DC, IO	✓	✓	✓	✓	✓	✓				
Restless Flycatcher	<i>Myiagra inquieta</i>	13	8	DC				✓	✓					
Jacky Winter	<i>Microeca fascians</i>	1	1	DC	✓									
Red-capped Robin	<i>Petroica goodenovii</i>	27	9	DC	✓			✓						
Hooded Robin	<i>Melanodryas cucullata</i>	2	2	DC	✓			✓						
Rufous Whistler	<i>Pachycephala rufiventris</i>	3	3	DC				✓	✓					
Grey Shrike-thrush	<i>Colluricincla harmonica</i>	213	50	DC, IO	✓	✓	✓	✓	✓	✓				
Magpie-lark	<i>Grallina cyanoleuca</i>	527	67	DC, IO	✓	✓	✓	✓	✓	✓	✓			
Crested Shrike-tit	<i>Falcunculus frontatus</i>	6	3	DC				✓	✓					
Crested Bellbird	<i>Oreoica gutturalis</i>	1	1	DC	✓									
Ground Cuckoo-shrike	<i>Coracina maxima</i>	4	2	DC		✓		✓						
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>	59	33	DC	✓	✓	✓	✓	✓					
White-winged Triller	<i>Lalage sueurii</i>	99	21	DC	✓	✓		✓	✓	✓				
Southern Scrub-robin	<i>Drymodes brunneopygia</i>	2	2	DC			✓	✓						
Chestnut-crowned Babbler	<i>Pomatostomus ruficeps</i>	108	16	DC	✓	✓		✓						
Chirruping Wedgebill	<i>Psophodes cristatus</i>	19	9	DC	✓		✓	✓						
White-fronted Chat	<i>Epthianura albifrons</i>	18	4	DC, IO		✓		✓	✓			✓		
Crimson Chat	<i>Epthianura tricolor</i>	80	13	DC	✓	✓		✓						
Orange Chat	<i>Epthianura aurifrons</i>	8	2	DC		✓								
Weebill	<i>Smicromis brevirostris</i>	160	15	DC	✓			✓						
Southern Whiteface	<i>Aphelocephala leucopsis</i>	42	7	DC	✓	✓		✓						
Yellow Thornbill	<i>Acanthiza nana</i>	7	2	DC				✓						
Inland Thornbill	<i>Acanthiza apicalis</i>	31	3	DC	✓			✓						
Chestnut-rumped Thornbill	<i>Acanthiza uropygialis</i>	62	11	DC	✓	✓		✓						
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>	82	15	DC	✓	✓	✓	✓	✓					
Brown Songlark	<i>Cinchorhamphus cruralis</i>	7	1	DC, IO		✓						✓		
Rufous Songlark	<i>Cinchorhamphus mathewsi</i>	8	4	DC, IO	✓			✓	✓					
Little Grassbird	<i>Megalurus gramineus</i>	19	2	DC, IO						✓	✓			
Clamorous Reed-Warbler	<i>Acrocephalus stentoreus</i>	56	5	DC, IO		✓		✓		✓	✓		✓	
Spotted Harrier	<i>Circus assimilis</i>	1	1	DC		✓								
White-winged Fairy-wren	<i>Malurus leucopterus</i>	283	21	DC	✓	✓	✓	✓		✓				
Variegated Fairy-wren	<i>Malurus lamberti</i>	302	37	DC, IO	✓	✓	✓	✓	✓	✓				
White-breasted Woodswallow	<i>Artamus leucorhynchus</i>	74	13	DC	✓	✓		✓	✓					
Masked Woodswallow	<i>Artamus personatus</i>	927	37	DC, IO	✓	✓	✓	✓	✓	✓				
White-browed Woodswallow	<i>Artamus superciliosus</i>	1828	54	DC, IO	✓	✓	✓	✓	✓	✓			✓	✓
Black-faced Woodswallow	<i>Artamus cinereus</i>	16	3	DC, IO		✓		✓						
Brown Treecreeper	<i>Climacteris picumnus</i>	248	42	DC, IO	✓	✓		✓	✓	✓				
Mistletoebird	<i>Dicaeum hirundinaceum</i>	2	2	DC	✓			✓						
Spotted Pardalote	<i>Pardalotus punctatus</i>	1	1	DC				✓						
Striated Pardalote	<i>Pardalotus striatus</i>	20	14	DC, IO	✓	✓		✓	✓					
Striped Honeyeater	<i>Plectorhyncha lanceolata</i>	12	5	DC	✓			✓	✓					
Black Honeyeater	<i>Certhionyx niger</i>	1	1	DC					✓					
White-fronted Honeyeater	<i>Phylidonyris albifrons</i>	8	4	DC			✓	✓						

Menindee Lakes vertebrates

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
Singing Honeyeater	<i>Lichenostomus virescens</i>	65	20	DC, IO	✓		✓	✓		✓	✓			
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>	2095	59	DC, IO	✓	✓	✓	✓	✓	✓				
Yellow-throated Miner	<i>Manorina flavigula</i>	595	48	DC	✓	✓	✓	✓	✓	✓				
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>	57	16	DC, IO	✓	✓	✓	✓	✓					✓
Little Friarbird	<i>Philemon citreogularis</i>	200	32	DC		✓		✓	✓	✓				
Richard's Pipit	<i>Anthus novaeseelandiae</i>	6	2	DC, IO		✓								✓
Zebra Finch	<i>Taeniopygia guttata</i>	119	14	DC	✓	✓	✓	✓		✓				
Apostlebird	<i>Struthidea cinerea</i>	144	14	DC				✓	✓	✓				
Australian Raven	<i>Corvus coronoides</i>	264	52	DC, IO	✓	✓	✓	✓	✓	✓				
Little Crow	<i>Corvus bennetti</i>	100	13	DC, IO	✓	✓	✓	✓	✓					✓
White-winged Chough	<i>Corcorax melanorhamphos</i>	114	14	DC		✓		✓	✓					
Pied Butcherbird	<i>Cracticus nigrogularis</i>	77	36	DC, IO	✓	✓		✓	✓					
Grey Butcherbird	<i>Cracticus torquatus</i>	17	9	DC		✓		✓	✓					
Australian Magpie	<i>Gymnorhina tibicen</i>	107	36	DC	✓	✓	✓	✓	✓	✓				
Common Blackbird ⁵	<i>Turdus merula</i>	1	0	IO										✓
House Sparrow ⁶	<i>Passer domesticus</i>	4	1	DC, IO			✓	✓						✓
Common Starling ⁷	<i>Sturnus vulgaris</i>	38	9	DC	✓	✓	✓	✓	✓					
Reptiles														
Broad-Shelled River Turtle	<i>Chelodina expansa</i>	1	1	DS		✓								
Murray Turtle	<i>Emydura macquarii</i>	4	2	DS	✓			✓						
Nobbi	<i>Amphibolurus nobbi</i>	2	1	PF	✓									
Painted Dragon	<i>Ctenophorus pictus</i>	16	8	DS, NS, PF	✓	✓	✓	✓						
Central Bearded Dragon	<i>Pogona vitticeps</i>	21	9	NS, PF, IO	✓	✓	✓	✓						✓
Marbled Gecko	<i>Christinus marmoratus</i>	3	2	DS, NS				✓						
Spiny-tailed Gecko	<i>Diplodactylus ciliaris</i>	19	7	NS, PF	✓	✓	✓	✓						
Box-patterned Gecko	<i>Diplodactylus steindachneri</i>	5	2	NS, PF		✓		✓						
Tessellated Gecko	<i>Diplodactylus tessellatus</i>	13	8	NS, PF		✓		✓						
Tree Dtella	<i>Gehyra variegata</i>	120	21	DS, NS, PF	✓	✓	✓	✓	✓					
Bynoe's Gecko	<i>Heteronotia binoei</i>	38	14	DS, NS, PF, IO	✓	✓	✓	✓						
Beaded Gecko	<i>Lucasium damaeum</i>	48	11	NS, PF, IO	✓	✓	✓	✓	✓					
Smooth Knob-tailed Gecko	<i>Nephurus levis</i>	5	3	NS, PF	✓	✓	✓							
Beaked Gecko	<i>Rhynchoedura ornata</i>	8	2	NS, PF, PF				✓	✓					
Thick-tailed Gecko	<i>Underwoodisaurus milii</i>	1	1	PF				✓						
Carnaby's Wall Skink	<i>Cryptoblepharus carnabyi</i>	25	3	DS, NS	✓	✓		✓						
Saltbush Ctenotus	<i>Ctenotus olympicus</i>	1	1	PF				✓						
Regal Striped Skink	<i>Ctenotus regius</i>	117	11	DS, PF, PF, IO	✓	✓	✓	✓						
Barred Wedgesnout Ctenotus	<i>Ctenotus schomburgkii</i>	9	3	DS, PF		✓	✓	✓						
Unid. Ctenotus	<i>Ctenotus sp.</i>	2	1	DS				✓						
Tree Skink	<i>Egernia striolata</i>	6	3	DS, NS	✓			✓						
Unid. Egernia	<i>Egernia sp.</i>	1	1	DS	✓									
Broad-banded Sand Swimmer	<i>Eremiascincus richardsonii</i>	8	5	NS, PF	✓	✓	✓	✓						
Mueller's Skink	<i>Lerista muelleri</i>	3	2	DS, PF				✓						
Spotted Burrowing Skink	<i>Lerista punctatovittata</i>	4	2	NS, PF				✓						
Samphire Skink	<i>Morethia adelaidensis</i>	25	4	DS, PF	✓		✓	✓						
Boulenger's Skink	<i>Morethia boulengeri</i>	108	20	DS, NS, PF, IO	✓	✓	✓	✓	✓					
Stumpy-tailed Lizard	<i>Trachydosaurus rugosus</i>	17	6	DS, IO	✓	✓	✓	✓						

Common name	Scientific name	Total records ¹	No. of sites ²	Method ³	Habitat ⁴									
					SH	OCS	LCS	BB	RG	LS	SFM	DLH	OW	'Other'
Gould's Goanna	<i>Varanus gouldii</i>	15	2	DS, IO	✓	✓		✓						✓
Tree Goanna	<i>Varanus varius</i>	33	11	DS, NS, IO	✓			✓	✓					✓
Goanna	<i>Varanus</i> sp.	17	11	DS, NS	✓	✓	✓	✓						
Carpet Python	<i>Morelia spilota variegata</i>	2	1	IO	✓									
Peters' Blind Snake	<i>Ramphotyphlops bituberculatus</i>	3	3	PF		✓		✓						
Woodland Blind Snake	<i>Ramphotyphlops proximus</i>	1	1	PF				✓						
Mulga Snake	<i>Pseudechis australis</i>	2	1	DS, IO		✓								✓
Western Brown Snake	<i>Pseudonaja nuchalis</i>	2	-	IO										✓
Eastern Brown Snake	<i>Pseudonaja textilis</i>	12	4	DS, NS, IO	✓	✓		✓						
Brown Snake	<i>Pseudonaja</i> sp.	3	1	IO				✓	✓					
Coral Snake	<i>Simoselaps australis</i>	1	-	IO	✓			✓						
Short-tailed Snake	<i>Suta nigriceps</i>	1	1	NS			✓							
Curl Snake	<i>Suta suta</i>	3	2	NS, PF		✓		✓						
Bandy-Bandy	<i>Vermicella annulata</i>	1	1	PF				✓						
Frogs														
Green Tree Frog	<i>Litoria caerulea</i>	88	13	DS, NS, PF, IO	✓			✓	✓	✓				
Peron's Tree Frog	<i>Litoria peronii</i>	72	12	DS, NS, IO	✓	✓		✓						✓
Plains Froglet	<i>Crinia parinsignifera</i>	10	1	NS				✓						
Barking Marsh Frog	<i>Limnodynastes fletcheri</i>	38	7	NS, PF, IO	✓			✓						✓
Spotted Marsh Frog	<i>Limnodynastes tasmaniensis</i>	61	13	DS, NS, PF, IO	✓	✓		✓						
Unid. Marsh Frog	<i>Limnodynastes</i> sp.	4	4	PF, PF	✓			✓						
Trilling Frog	<i>Neobatrachus centralis</i>	5	3	PF, IO			✓	✓	✓					
Common Spadefoot Toad	<i>Neobatrachus sudelli</i>	4	1	PF, IO	✓			✓						✓
Spadefoot Toad	<i>Neobatrachus</i> sp.	2	1	PF	✓									

¹ Includes all records by all methods, although for the four abundant species mentioned in the text, incidental observations were not generally recorded. Note that the number of individuals recorded by hair tube and ultrasonic bat detectors could not be determined and, consequently, the minimum number of records is denoted by + when data from these techniques are included.

² Refers to records from established survey sites only and does not include sites at which most incidental observations were recorded.

³ Methods: D ultrasonic bat detector; DS diurnal search; HT hair tube; H harp trap; NS nocturnal search; PF pitfall trapping; IO incidental observation.

⁴ Habitat: habitat classes refer to the spatially dominant community present at each site (descriptions and abbreviations given in text). Note that the number of sites, and therefore effort, varied between habitat types. 'Other' habitats typically embrace non-native habitats, such as agricultural land, human structures, roads etc.

Table 2 Summary of the number of species for each vertebrate group recorded during the 2000-01 fauna survey (all methods), for each major habitat type.

Habitat Type	Mammals	Birds	Reptiles	Frogs	Total
Shrubland	12	66	22	5	105
Low Open Chenopod Shrubland	16	65	21	2	104
Low Canegrass Shrubland	11	43	17	1	72
Black Box Woodland	24	117	30	7	178
Red Gum Forest/Woodland	3	79	5	2	89
Lignum Swamp	0	43	0	1	44
Total (for all habitats)	25	164	39	7	235

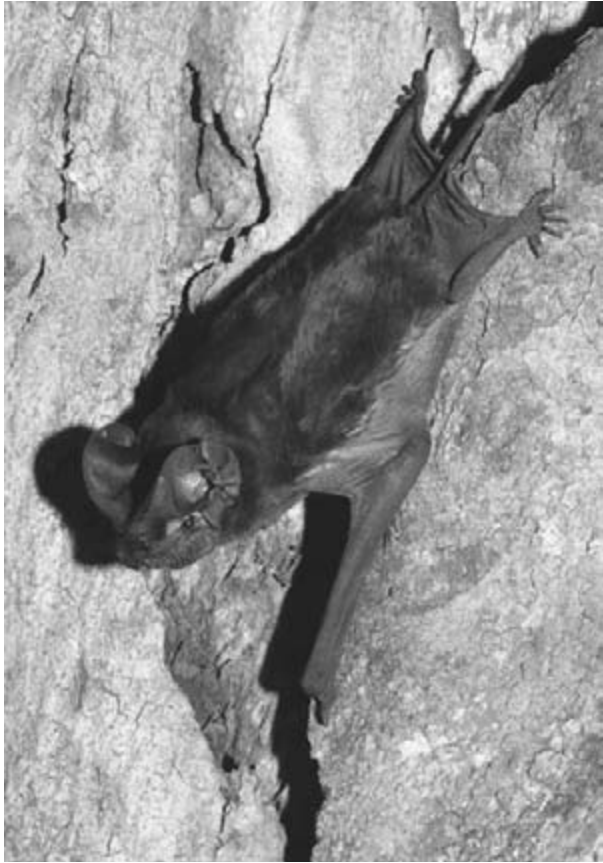


Figure 2 The White-striped Freetail Bat *Tadarida australis*, a species that is dependent on trees for roosting, was recorded during the survey in shrubland and Black Box woodland.

Scotorepens balstoni). Some groups of species have very similar calls (Freetail Bats *Mormopterus* sp. (southern form)/ *Mormopterus* sp. (inland form) and Lesser Long-eared Bat *Nyctophilus geoffroyi*/ Gould's Long-eared Bat *N. gouldi*/ Greater Long-eared Bat *N. timoriensis*/ Large-footed Myotis *Myotis macropus*), and for these groups, identification to species level was not possible.

Gould's Wattled Bat *Chalinolobus gouldii*, Little Broadnosed Bat *Scotorepens greyii* and Little Forest Bat *Vespadelus vulturnus* yielded the most records (both census techniques), and the Lesser Long-eared Bat *Nyctophilus geoffroyi* was also commonly recorded. The majority of bat species were recorded from all the sampled habitat classes with most records from the Black Box Woodland. Two species listed as threatened in NSW, Little Pied Bat *Chalinolobus picatus* and Inland Forest Bat *Vespadelus baverstocki*, were recorded from six and three sites, and two and three habitats respectively (Table 1).

Five species of dasyurid were recorded during the survey (Table 1). Giles' Planigale *Planigale gilesi* (also known as Paucident Planigale) was the most widespread species, recorded from seven sites and mostly from habitat dominated by Black Box Woodland. The Fat-tailed Dunnart *Sminthopsis crassicaudata* was recorded from four sites — most of these were from Chenopod Shrubland. The three other dasyurid species recorded, Narrow-nosed Planigale *P. tenuirostris*, Common Dunnart *S. murina* and Striped-faced Dunnart *S. macroura* were each recorded from a single site.

The Narrow-nosed Planigale was recorded from Black Box Woodland and the Striped-faced Dunnart from an ecotone site of Black Box Woodland/ Shrubland. The Common Dunnart was recorded from Low Canegrass Shrubland.

The Western Grey Kangaroo and the Red Kangaroo were commonly encountered throughout the survey area, particularly in Kinchega National Park. Both species were recorded from a range of habitat types. The majority of Red Kangaroo records were from Chenopod Shrubland while most Western Grey Kangaroos were seen in Black Box Woodland.

Six species of introduced mammal were recorded during the fauna survey. With the exception of the House Mouse, which was regularly recorded in pitfall buckets, hair tubes and in Elliott traps, most introduced species were recorded incidentally, usually from habitat types dominated by Black Box Woodland. Mice were recorded in higher numbers during the spring survey when the species was considered by local farmers to be in plague numbers (D. Poulton pers. comm.).

Birds

Spring and summer surveys produced 3,447 records of 165 species (16,790 individuals) from standard sampling techniques and opportunistic observations (Table 1). One hundred and eighteen of these species were terrestrial birds, the focus of this investigation.

Formal diurnal bird censuses on 71 sites revealed 140 species of birds. Species richness was highest in the timbered communities of Black Box Woodland and Red Gum Forest/Woodland, although Black Box Woodland was more intensely surveyed than other communities. Lignum Swamps along with these two timbered communities supported the highest densities and diversities of bird species in both spring and summer. The three sites in Lignum Swamp were characterised by insubstantial swamps and typically abutted Black Box Woodland with scattered trees throughout, which added structural complexity. Communities with the least structural complexity (i.e. the Low Shrublands) supported the lowest densities and diversity of birds.

The influence of season on the Menindee Lakes fauna was most pronounced for birds, with the rate of observation across the study area significantly higher in spring than summer ($p < 0.05$). One hundred and twenty six species were recorded during spring censuses and 111 recorded during summer ($p < 0.05$). Seasonal differences were insignificant for the Low Shrublands and the riparian Red Gum Forest/Woodland communities while the density of birds recorded for other communities was significantly reduced in summer ($p < 0.05$). Numbers of nectarivores and insectivores were particularly high in Shrubland in early October when species of *Eremophila* and *Acacia* were flowering. Several bird species that frequently forage in the Chenopod Shrubland were recorded breeding in Black Box Woodland during spring (e.g. Chestnut-rumped *Acanthiza uropygialis* and Yellow-rumped Thornbill *A. chrysorrhoa*). Nesting in Black Box Woodland was particularly pronounced for species of the families Cacatuidae and Psittacidae (corellas, cockatoos, parrots etc.), which nest in tree hollows and may forage for seed far from woodland. Nesting densities of birds of prey were similarly high in woodland communities.

Spring was characterised by widespread breeding activity and an influx of nomadic species. Species such as the Little Friarbird *Philemon citreogularis* and Horsfield's Bronze-Cuckoo *Chrysococcyx basalis* were abundant and conspicuous in spring but rarely recorded in summer. In all, 38 species that were recorded at sites in spring were not observed in summer, while only six recorded species were absent in spring. The Mistletoebird *Dicaeum hirundinaceum* and White-fronted Honeyeater *Phylidonyris albifrons* were recorded only in summer while foraging in tall shrubs heavily parasitised by Mistletoe. Records of two aerial insectivores were also confined to summer — the White-throated Needletail *Hirundapus caudacutus* was observed once and the Fork-tailed Swift *Apus pacificus* three times. Both are migratory species that breed in Asia, and arrive in Australia in October and depart in April. Both are scarce in southern Australia until December or January (Emison *et al.* 1987).

Only three species of nocturnal birds were recorded during the systematic component of the survey: Barn Owl *Tyto alba*, Southern Boobook Owl *Ninox novaeseelandiae* and the Australian Owlet-Nightjar *Aegotheles cristatus*. In addition to formal nocturnal censusing, all were observed roosting in tree hollows during daylight. Barn Owls and Southern Boobook Owls were found roosting in River Red Gum, while the Australian Owlet-Nightjar and Southern Boobook Owl were found in the hollows of Black Box. An additional nocturnal species, the Tawny Frogmouth *Podargus strigoides*, was recorded opportunistically during the survey.

Nocturnal censuses showed that the Australian Owlet-Nightjar was most common in Black Box Woodland and scattered Black Box trees of Low Chenopod Shrubland. The two owl species apparently partitioned the timbered communities, with the Barn Owl hunting in the more open Shrubland communities and fringing Black Box while the Southern Boobook Owl utilised the Red Gum Forest/Woodland and, to a lesser degree the Black Box Woodland community. This pattern was evident despite the use of taped calls which attracted owls from some distance.

Twenty-six bird species were only recorded opportunistically. As these tended to be the less common and usually sparsely distributed species they included a higher proportion of rare, threatened or endangered species, such as Australian Bustard *Ardeotis australis*, Red-tailed Black-Cockatoo *Calyptorhynchus banksii* and Major Mitchell's Cockatoo *Cacatua leadbeateri*.

Reptiles

A total of 758 reptiles was recorded by all survey methods, representing 8 families and at least 39 species (Table 1). These families include Chelidae (2 species), Agamidae (3), Gekkonidae (10), Scincidae (11), Varanidae (2), Boidae (1), Typhlopidae (2) and Elapidae (8) (Table 1).

Several species were exceedingly common and widespread, especially the Stumpy-tailed Lizard *Trachydosaurus rugosus*, which was commonly observed across the study area during the spring survey, often feeding on the Australian Plague Locust *Chortoicetes terminifera*. It was so abundant that individual incidental records were not collected. Other relatively common species, in terms of the number of study sites at which they were recorded, were Tree Dotted Gecko *Gehyra variegata* (18 study sites), Boulenger's Skink *Morethia*

boulengeri (18), Bynoe's Gecko *Heteronotia binoei* (13), Regal Striped Skink *Ctenotus regius* (11), Beaded Gecko *Lucasium damaeum* (11), Central Bearded Dragon *Pogona barbata* (9) and Tree Goanna *Varanus varius* (9). However, the majority of reptile species were recorded infrequently (Table 1).

Most reptile species recorded during the survey, including the majority of skinks and gecko species, were located in Black Box Woodland, although the sampling effort for this habitat type exceeded that for any other habitat type. Black Box Woodland also yielded the only survey records of the Marbled Gecko *Christinus marmoratus*, Saltbush Ctenotus *Ctenotus olympicus*, two *Lerista* species, Bandy Bandy *Vermicella annulata* and the Woodland Blind Snake, a species newly recorded for the study area.

Almost as many species were recorded from Shrubland and Chenopod Shrubland, despite a substantially smaller effort (i.e. fewer sites). Low Canegrass Shrubland on the northern margin of Lake Menindee revealed a relatively high species richness (17), including seven gecko species and the only record of Short-tailed Snake *Suta nigriceps*. Very few records were collected for Red Gum Woodland (11 individuals of five common species).

During the survey in February and March (2001), extremely hot weather conditions prevailed, and overall diurnal reptile activity was noticeably diminished at certain times.

Frogs

Two species of Hylidae (Tree Frogs) and at least five species of Myobatrachidae (Southern Frogs) were recorded during the survey, usually via pitfall trapping or nocturnal searching, although the Green Tree Frog *Litoria caerulea* was commonly observed on roads during rainy periods in spring. The Green Tree Frog and Peron's Tree Frog *Litoria peronii* accounted for over half of all frog records from the survey and were found at 10 and 12 study sites respectively, while the two *Limnodynastes* species comprised a further third of all records (Table 1). Two other genera, *Crinia* and *Neobatrachus*, comprised the few remaining records.

All frog species recorded during the survey were found in Black Box Woodland and all but two species were also found in Shrubland; the Green Tree Frog was virtually the only frog species recorded in Red Gum Woodland. Very few individuals were recorded in Shrubland and Chenopod Shrubland; these habitat types were generally 'dry' and located further from water.

Threatened Fauna

The categories, definitions and criteria used to describe the threatened status of fauna are those defined in the IUCN Red List Categories (IUCN 2000). In order to qualify for a threat category, a taxon must meet one or more assessment criteria, based on features such as numbers of individuals and populations, previous or projected declines in numbers or habitat, extent of occurrence, area of occupancy and extreme fluctuations in numbers or habitat. The threat status of species in a national or state context is derived (on-line) from the *Environment Protection and Biodiversity Conservation Act 1999* and the *New South Wales Threatened Species Conservation Act 1995*, respectively.

Table 3 Threatened extant species of the Menindee Lakes, based on 2000-01 fauna survey records and historical records post-1980 (for two 1:100,000 maps: Menindee 7333, Nartooka 7433). Species for all categories of conservation status (IUCN, national, state, regional) are included.

Species	Common name	Survey 2000-01	Conservation status ¹				Source of regional status
			IUCN	Aust	NSW	Regional	
Mammals							
Dasyuridae							
<i>Antechinomys laniger</i>	Kultarr		DD		End	✓	Ayers <i>et al.</i> (1996), Dickman & Read (1992)
<i>Planigale tenuirostris</i>	Narrow-nosed Planigale	✓				✓	Dickman & Read (1992)
<i>Planigale gilesi</i>	Giles' Planigale	✓				✓	Dickman & Read (1992)
<i>Sminthopsis murina</i>	Common Dunnart	✓				✓	Dickman & Read (1992)
<i>Sminthopsis macroura</i>	Stripe-faced Dunnart	✓			Vul	✓	Dickman & Read (1992)
Phalangeridae							
<i>Trichosurus vulpecula</i>	Common Brushtail Possum	✓				✓	Mazzer <i>et al.</i> (1998), Dickman <i>et al.</i> (1993)
Emballonuridae							
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail-bat				Vul	✓	Ayers <i>et al.</i> (1996), Mazzer <i>et al.</i> (1998)
Vespertilionidae							
<i>Chalinolobus picatus</i>	Little Pied Bat	✓			Vul	✓	Ayers <i>et al.</i> (1996), Dickman <i>et al.</i> (1993)
<i>Vespadelus baverstocki</i>	Inland Forest Bat				Vul	✓	Mazzer <i>et al.</i> (1998)
Muridae							
<i>Hydromys chrysogaster</i>	Water-rat	✓				✓	Mazzer <i>et al.</i> (1998), Dickman <i>et al.</i> (1993)
Canidae							
<i>Canis lupus dingo</i>	Dingo					✓	Mazzer <i>et al.</i> (1998)
Birds							
Phasianidae							
<i>Coturnix ypsilophora</i>	Brown Quail	✓				✓	Smith <i>et al.</i> (1994)
Accipitridae							
<i>Lophoictinia isura</i>	Square-tailed Kite				Vul	✓	Ayers <i>et al.</i> (1996)
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard	✓			Vul	✓	Ayers <i>et al.</i> (1996)
Falconidae							
<i>Falco hypoleucos</i>	Grey Falcon				Vul	✓	Ayers <i>et al.</i> (1996)
Gruidae							
<i>Grus rubicunda</i>	Brolga				Vul	✓	Ayers <i>et al.</i> (1996)
Otididae							
<i>Ardeotis australis</i>	Australian Bustard	✓			End	✓	Ayers <i>et al.</i> (1996)
Burhinidae							
<i>Burhinus grallarius</i>	Bush Stone-curlew				End		
Cacatuidae							

Species	Common name	Survey 2000-01	Conservation status ¹				Source of regional status
			IUCN	Aust	NSW	Regional	
<i>Calyptrorhynchus banksii</i>	Red-tailed Black-Cockatoo	✓			Vul	✓	Ayers et al. (1996)
<i>Cacatua leadbeateri</i>	Major Mitchell's Cockatoo	✓	LR		Vul	✓	Ayers et al. (1996)
Psittacidae							
<i>Polytelis anthopeplus</i>	Regent Parrot	✓		End	End	✓	Ayers et al. (1996)
Petroicidae							
<i>Drymodes brunneopygia</i>	Southern Scrub-robin	✓			Vul	✓	Ayers et al. (1996)
<i>Melanodryas cucullata</i>	Hooded Robin	✓			Vul		
Pachycephalidae							
<i>Falcunculus frontatus</i>	Crested Shrike-tit	✓				✓	Smith et al. (1994)
<i>Pachycephala inornata</i>	Gilbert's Whistler				Vul	✓	Ayers et al. (1996)
Passeridae							
<i>Staenopleura guttata</i>	Diamond Firetail				Vul	✓	Smith et al. (1994)
Reptiles							
Chelidae							
<i>Chelodina expansa</i>	Broad-shelled River Turtle	✓				✓	Mazzer et al. (1998), Sadlier & Pressey (1994), Sadlier et al. (1996)
<i>Emydura macquarii</i>	Murray Turtle	✓				✓	Mazzer et al. (1998), Sadlier & Pressey (1994), Sadlier et al. (1996)
Gekkonidae							
<i>Christinus marmoratus</i>	Marbled Gecko	✓				✓	Mazzer et al. (1998), Sadlier & Pressey (1994)
<i>Gehyra dubia</i>	Dubious Dtella					✓	Sadlier & Pressey (1994), Sadlier et al. (1996)
Scincidae							
<i>Ctenotus uber</i> ²	Uber Striped Skink					✓	Mazzer et al. (1998), Sadlier & Pressey (1994), Sadlier et al. (1996)
<i>Lerista xanthura</i>	Yellow-tailed Plain Slider					✓	Sadlier et al. (1996)
Boidae							
<i>Morelia spilota variegata</i>	Carpet Python	✓				✓	Mazzer et al. (1998), Sadlier et al. (1996)
Elapidae							
<i>Pseudechis australis</i>	Mulga Snake	✓				✓	Mazzer et al. (1998)
<i>Suta nigriceps</i>	Short-tailed Snake	✓				✓	Mazzer et al. (1998), Sadlier & Pressey (1994), Sadlier et al. (1996)
Frogs							
Myobatrachidae							
<i>Crinia parinsignifera</i>	Plains Froglet	✓				✓	Sadlier & Pressey (1994), Sadlier et al. (1996)

¹ Conservation status (following IUCN (2000) and NRE (2000)): End Endangered, Vul Vulnerable, LR Lower Risk - near threatened, DD Data deficient.

² Due to recent taxonomy changes (Hutchinson & Donnellan 1999), in the Menindee Lakes area this is now either *Ctenotus orientalis* or *C. olympicus*.



Figure 3 The nocturnal Smooth Knob-tailed Gecko *Nephurus levis* was recorded during the survey in shrubland habitats.

Regional significance is based on published documentation. The significance rating may vary, according to the source and the year, and is generally influenced by the extent of the area being considered. In many cases, the significance ranking is for western New South Wales, an extensive area that covers a broad environmental gradient. In this paper the principal sources of regional status for individual species include Dickman and Read (1992), Dickman *et al.* (1993), Smith *et al.* (1994), Sadlier and Pressey (1994), Sadlier *et al.* (1996), Ayers *et al.* (1996) and Mazzer *et al.* (1998).

Seventeen species, all mammals, recorded from western New South Wales are classified as *Extinct* in the state. These species include the Western Quoll *Dasyurus geoffroii*, Red-tailed Phascogale *Phascogale calura*, Numbat *Myrmecobius fasciatus*, Western Barred Bandicoot *Perameles bougainville*, Bilby *Macrotis lagotis*, Pig-footed Bandicoot *Chaeropus ecaudatus*, Burrowing Bettong *Bettongia lesueur*, Brush-tailed Bettong *Bettongia penicillata*, Eastern Hare-wallaby *Lagorchestes leporides*, Bridled Nailtail Wallaby *Onychogalea fraenata*, Northern Hairy-nosed Wombat *Lasiorhinus krefftii*, Greater Stick-nest Rat *Leporillus conditor*, Lesser Stick-nest Rat *L. apicalis*, Desert Mouse *Pseudomys desertor*, Sandy Inland Mouse *P. hermannsburgensis*, Mitchell's Hopping-mouse *Notomys mitchelli*, and Gould's Mouse *Pseudomys gouldii*. Gould's Mouse and Eastern Hare-wallaby are also classified as extinct at an international (IUCN) level.

Overall, at least 305 terrestrial vertebrate species have been recorded from the area, including 18 species that are considered officially threatened in an international, national, or state (New South Wales) context (Table 3). At least another 18 species are locally threatened.

Of the mammal species that are considered significant, one has been assigned an IUCN conservation status, five are significant in New South Wales, and 11 are significant in the region (Table 3). A number of bird species are also officially considered significant — 15 species are listed as threatened in an international (1 species), national (1), state (13) or regional (13) context. Whilst there are no reptile or frog species that have been assigned an IUCN, national or state conservation status, nine reptile species and one frog species are considered regionally significant.

Eight bird species are also protected under the Japan Australia Migratory Birds Agreement (JAMBA) or the China Australia Migratory Birds Agreement (CAMBA): Black-tailed Godwit *Limosa limosa*, Common Sandpiper *Actitis hypoleucos*, Sharp-tailed Sandpiper *Calidris acuminata*, Pectoral Sandpiper *Calidris melanotos*, Glossy Ibis *Plegadis falcinellus*, Great Egret *Ardea alba*, White-bellied Sea-Eagle *Haliaeetus leucogaster*, and Caspian Tern *Sterna caspia*.

Discussion

Fauna of the Menindee Lakes

The Menindee Lakes exhibit an exceptionally high faunal diversity. This can be attributed to the wide variety of different habitats types present in the area, including floodplain habitat types such as billabongs, riverine lakes, terminal wetlands, and dry floodplains as well as riverine eucalypt woodlands, shrublands, grasslands and dune communities (Schodde 1994, Young 2001).

The changed regime resulting from the Menindee Lakes scheme has resulted in an increased abundance for some native species while at the same time, the abundance of other native species has declined. The more secure water supply provides extensive wetland habitat for waterbirds, micro- and macro-invertebrates, fish, amphibians, and aquatic reptiles and mammals such as tortoises and the Water Rat. However, permanent flooding has interrupted the cycle of drying which has disadvantaged many native species including terrestrial invertebrates, small mammals and reptiles that colonise the deep cracks that develop in lake beds as the soils dry out. Shrub-dwelling terrestrial bird species also inhabit the vegetation that develops on dry lake-beds (Briggs and Jenkins 1997). The lack of drying cycle has benefited introduced species such as the European Carp *Cyprinus carpio*, which has been able to exploit the changed ecosystem and compete more successfully than the native fish species (Mussared 1997, Koehn *et al.* 2000).

The Menindee Lakes are also important for migratory bird species. At least 20 species are summer migrants, 13 of which are known to breed locally, and three are winter visitors, none of which is known to breed locally. Of these migrants, seven regularly migrate beyond Australia (6

breeding in Asia, one breeding locally but wintering in northern Australia and islands to the north). The list of intercontinental migrants appears to be incomplete, and several common migratory shorebirds would be expected to be added with further observation (e.g. Red-necked Stint *Calidris ruficollis*).

The spring of 2000 was notable for the population irruptions of two agricultural pest species in the study area, the Australian Plague Locust *Chortoicetes terminifer* and House Mouse *Mus musculus*, and this probably influenced the occurrence and abundance of those vertebrate species that prey on these pest species. Field observations confirmed this for a number of predators. The Plague Locust provided abundant prey for many insectivores, particularly migratory species such as the White-browed Woodswallow *Artamus leucorhynchus* and Masked Woodswallow *A. personatus* which flocked together in groups of up to 250 individuals, as well as the Stumpy-tailed Lizard *Trachydosaurus rugosus*. Flocks of Black Kite *Milvus migrans* were common and widespread in spring and frequently observed feeding on flightless locusts. It is likely that both the Black Kite and the Black-shouldered Kite *Elanus axillaris* preyed on mice, explaining an influx of these raptors during spring.

Menindee Lakes as Habitat

The study area forms an important section of a significant north-south corridor of woodland extending through the arid shrublands of New South Wales. While most of the fauna of this corridor is characteristic of arid and semi-arid environments (Eyrean in origin) (Schodde 1994), northern (or Torresian) elements (e.g. Red-tailed Black Cockatoo) extend south along the corridor and mesic, south-eastern Australian (Bassian) elements (e.g. Crested Shrike-tit) extend north (Blakers *et al.* 1984).

Eucalypt woodlands comprise only 8% of the vegetation types in the Western Division of New South Wales and are identified as the most critical of habitats (Schodde 1994). Eucalypt woodlands are more common in the study area as they depend on periodic influxes of water from the Darling River system for regeneration and survival. Woodlands dominated by Black Box are found on the floodplains of the Darling River and Great Darling Anabranch and fringe most of the ephemeral lakes. Red Gum woodlands are more limited and are mostly restricted to major channels and waterways and the fringes of the permanent or near permanent lakes.

Woodlands are critical habitats for a range of terrestrial fauna species in the region. Hollows develop in mature eucalypts and provide an important resource for many fauna species, many of which also use habitat types other than woodlands for food resources. Mature eucalypts provide nest-sites for cockatoos and other parrots, owls, kingfishers, nightjars, martins, roosting and foraging habitat for bats, den sites for Common Brushtail Possums and shelter, foraging and basking sites for reptiles such as the Tree Goanna, Tree Skink and Carpet Python as well as several arboreal species of gecko. Many of the fauna species considered significant (Table 3) are dependent upon woodland habitats for nesting and foraging. This survey found that bird species richness was highest in the timbered communities of Black Box Woodland and Red Gum Forest/Woodland. Although eucalypt woodland is limited in distribution and extent in the Western Division of New South Wales, it exhibits the greatest diversity of

regular avian inhabitants (Schodde 1994, Smith and Smith 1994). Riverine eucalypt woodland is one of the most critical habitats for maintaining diversity in the bush bird fauna as it encompasses the greatest number of species in relatively limited areas (Schodde 1994).

Ephemeral lakes are a characteristic feature of the floodplains of the Darling River and Great Darling Anabranch. The dual wet and dry nature of these intermittently-flooding lakes greatly contributes to high levels of biodiversity in semi-arid regions. Lake-bed soils are generally composed of heavy, grey to grey-brown clays that shrink and crack on drying. These cracks, which may be up to 2 metres deep, allow animal movement through the soil and provide habitat for many fauna species (Mussared 1997, Jenkins 1999, Young 2001). Opportunistic lake-bed dwellers include terrestrial invertebrates, planigales and dunnarts. Several species of reptile have also been recorded from the middle of dry lake-beds south of the Menindee Lakes system, including Central Bearded Dragon, Samphire Skink, Boulenger's Skink, Peter's Blind Snake, Tessellated Gecko, and *Tympanocryptis* species (Briggs *et al.* 2000). Dry lake-beds also provide habitat for a number of shrub-dwelling bird species (Briggs *et al.* 2000). The period of time for which a lake remains dry is important – small mammals and reptiles that reinvade lakes when they dry out following floods are unlikely to move in and out of lakes when they are flooded annually (Briggs and Jenkins 1997).

Of all the lakes in the Storage Scheme, Lakes Malta, Balaka and Bijijie are the most ephemeral. Of these three lakes, Lake Malta is currently the least affected by the Storage Scheme and appears to be in a relatively natural condition. Of the more permanent lakes, Lake Cawndilla was found to be relatively rich in terms of the composition of its faunal community. The highest numbers of species of mammals, reptiles and frogs were recorded from sites in the vicinity of this lake, as were high numbers of birds. Lake Wetherell is considerably different to the ephemeral lakes in the habitat it provides and therefore its avian community. When compared with the 'lower lakes', the non-fluvial habitats of the northern ephemeral lakes are generally comprised of taller shrublands on sandy substrates and include patches of Belah and occasional Mulga.

Around Lake Tandure, Clamorous Reed-Warblers *Acrocephalus stentoreus* inhabited the reed-beds that had established in some of the shallower sections of this and other lakes and were often recorded with the Little Grassbird *Megalurus gramineus*, particularly in Lignum that did not have a eucalypt overstorey. Historic records suggest that both of these species have increased in the Menindee Lakes area, probably as the result of more constant water-levels and inundation allowing the proliferation of reeds and Lignum (DLWC 1996).

Bird species of Chenopod Shrublands were more frequently recorded in the precincts of the 'lower lakes' while species of taller shrublands were more frequently recorded from around the 'upper lakes'. Construction of the Menindee Lakes Storage Scheme and subsequent management has resulted in the loss of woodland and an increase in permanent water and frequently-flooded habitats. The composition of the Menindee Lakes' avifauna follows an overall trend for western NSW (Smith *et al.* 1994) of a decrease in woodland birds and an associated increase in waterbirds.

New Records

The 2000-01 survey yielded several records of new vertebrate species for the area, including the Striped-face Dunnart *Sminthopsis macroura*, Regent Parrot, and Woodland Blind Snake, as well as additional records for uncommon species.

The Stripe-faced Dunnart is classified as *Vulnerable* in NSW (*New South Wales Threatened Species Conservation Act* 1995). Prior to this survey the species had not been recorded in the study area, the closest NSW records originating from the area of Mootwingee National Park, approximately 100 km north of Menindee (Dickman and Read 1992). This arid-zone species is sparsely distributed throughout much of inland central and northern Australia. It is more commonly recorded in the north than in the south of the Western Zone of New South Wales (Ayers *et al.* 1996). It is a poorly known species that has flexible habitat preferences (Dickman and Read 1992, Morton 1995).

A Regent Parrot was observed during the survey in a mature Red Gum along the upper reaches of Tandou Creek. This parrot feeds in Mallee-dominated vegetation communities and breeds in Red Gum and Black Box Woodlands with mature, hollow-bearing trees (Higgins 1999). The record from upper Tandou Creek is likely to be of a vagrant as the area lacks Mallee Woodland where the species forages for the seeds of grasses and herbaceous plants. The closest historical record for this species originates in 1996 from the

Pooncarie district (NPWS 2000), 100 km away, and that area provides both suitable foraging and breeding habitat.

The Woodland Blind Snake is a relatively robust blind snake and attains an average length of 50cm (Cogger 2000). It exhibits a broad distribution across eastern Australia, from northern Victoria to the base of Cape York in northern Queensland. Like all members of its family, it is a specialised soil-dweller and subsists on ants or termites (Coventry and Robertson 1991).

Conclusion

The Menindee Lakes system, including the Darling River and Great Darling Anabranch, has high faunal diversity and is important in a regional (and even continental) context for biodiversity conservation. The area of woodlands in the region is proportionately small, and typically restricted to floodplains and the periphery of lakes. Most of the existing woodlands in the system are dominated by either Black Box or Red Gum, and are restricted to those areas close to permanent water or prone to regular inundation. Eucalypt woodlands are identified as the most critical habitat in western New South Wales for maintaining terrestrial vertebrate biodiversity. Within the Menindee Lakes area the Black Box Woodlands are significant because they are naturally limited in extent, they have specific water regime requirements and all have been greatly reduced in area due to past changes to these regimes principally caused by agricultural practices and the Menindee Lakes Storage Scheme.

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Appendix I Fauna Survey Techniques

APPENDIX I

Bird Census

The census of birds was conducted using a standardised area search (Loyn 1986) — three hectares were searched over 20 minutes — at each predetermined site on four occasions, twice in spring and twice in summer. Extra bird sites were searched only once in each season. During each search, the observer moved through the selected area and recorded numbers of all birds seen or heard. Birds identified from adjacent areas were recorded separately. These searches were conducted between dawn and mid-day and at dusk. Although periods of hot weather were generally avoided, the reduced opportunities for mild weather searches during the hot months of summer necessitated some searches during periods of high temperatures. The probability of detecting individuals during these periods was therefore reduced. Similarly, some searches during periods of moderate winds were unavoidable with a resultant reduction in the detectability of birds. Time of day also exerts a strong influence on activity and detectability, which peak at dawn and dusk (Bart and Herrick 1984, Slater 1994). Where possible, optimal time and conditions were preferentially allocated to the censusing of standard sites. Several species resident within the study area were unlikely to be recorded as their habitat was either not sampled or under-sampled due to its distance from lake, water course or the influence of watertable e.g. White-browed Treecreeper *Climacteris affinis* is typically a species of Belah *Casuarina pauper* Woodland which was more distant from the water-bodies in the study area. Waterbirds were not targeted but recorded only as chance observations or when they occurred on sites being surveyed.

Pitfall trapping for ground vertebrates (small mammals, reptiles and frogs)

Pitfall trapping is a long-recognised survey technique that has been widely used in Australia. While installation is relatively labour-intensive, pitfall traps are easily monitored and are the most effective trapping technique in semi-arid environments. In addition to providing relatively large numbers of the more common species, they are more likely to record rare or cryptic species than other trapping and census techniques.

Twelve buckets. (20L, 290 mm diam. opening x 400 mm deep) were arranged in a line. A 'Y'-shaped fibreglass flywire drift-fence, held erect by metal pegs, was placed over each bucket, such that each 'arm' of the drift-fence extended at least 2 m from the centre. Buckets were not baited and were monitored daily.

Elliott trapping

Twenty-five aluminium Elliott traps (collapsible aluminium live traps 9 x 10 x 33 cm) were positioned in two lines at each site and monitored daily for four days in each season. Each trap was baited with a blend of honey, peanut butter and oats. Elliott trap captures comprised only House Mice, but for one Tree Skink *Egernia striolata*, and this trapping technique was discontinued early during the first summer field-trip once it was apparent that the likelihood of trapping other vertebrates was extremely low.

Hair analysis — hair-tube

Hair-tubes rely on an animal being attracted to bait in a conical tube with an adhesive surface. As the animal investigates the bait, some of its hair sticks to the surface, which can be later analysed to identify the species. During this survey, a line of 10 tubes was installed at each site, in each season, and left in place for four days. Half of the hair-tubes at each site were baited with a mixture of honey, peanut butter and oats, and the other half with peanut butter, oats and tuna oil. This technique is particularly useful for detecting small mammal species that are cryptic or difficult to trap.

Call-playback

As many of the species that occur in the area are nocturnal, call-playback censuses were conducted at each site (after Kavanagh and Peake 1993, Loyn *et al.* 2001). During these censuses, taped calls of six nocturnal bird species and eleven frog species were amplified and played at night to elicit a response from animals that potentially reside on the site or adjacent areas. After the call of each species was broadcast, the area was scanned by spotlight to detect nocturnal birds or frogs. Where possible, call-playback was conducted during optimal weather conditions. Call-playback for frogs was discontinued early in the summer field-trip because the technique proved to be ineffective. The results from the frog playback sessions for the spring and early summer surveys yielded nothing. This was to be expected given that only certain frog species are known to respond to call-playback and that these species do not include any that are resident around the Menindee Lakes. Calls of the following nocturnal bird species were broadcast: Masked Owl, Barn Owl, Boobook Owl, Barking Owl, Tawny Frogmouth, Australian Owlet Nightjar. All predetermined sites were censused for these nocturnal bird species at least once during spring surveys and at least once in summer.

Herpetofauna searches

In addition to pitfall trapping for reptiles and frogs, area-constrained searches were conducted at each site in order to detect arboreal or semi-arboreal species (e.g. some geckoes) that are rarely captured in pitfall traps, and those species, such as goannas and relatively large elapid snakes that can escape from

pitfall buckets. Active searches were conducted along a site transect and involved the hand-sampling of a specified area (10m x 25m), and incorporate actions such as prising loose bark from the trunks of both live and dead trees, and overturning logs, rocks, litter etc. The time taken to carry out an active search varied according to the structural complexity of the site. At least two diurnal and two nocturnal searches were carried out at each pre-determined site in each sampling season.

Each diurnal search was undertaken in fine weather and above a threshold ambient temperature of 20°C so as to record active individuals in addition to sheltering or cryptic reptiles. During each search, individual reptiles were recorded along with a suite of microhabitat characteristics to describe their location, including substrate and height of individual above the ground.

Bats — harp trapping

Harp-trapping of bats is required to confirm identifications and record reference calls of captured individuals for the detector analysis, as well as sampling some species that may not easily be recorded by detectors. Harp-traps were positioned at each site largely at optimal trapping locations, such as dams and near other water bodies, or in 'fly-ways' where the vegetation was sufficiently thick to constrict flyways. Traps were set over three nights in each trapping season. Captured bats were identified and their sex and developmental status determined.

Bats — *Anabat* recording

Ultrasonic bat detectors were linked to a delay switch and tape-recorder so as to automatically record all bats heard at a site throughout the night. These computerised detector units were set and left unattended, enabling multiple sites to be sampled simultaneously over the entire night. Calls were automatically downloaded to computer, and species identified based on the frequency and shape characteristics of calls when viewed with *Anabat 6* software (from Titley Electronics Pty Ltd). The call characteristics of each species were determined by careful examination of reference calls recorded from identified individuals trapped during the study. Where insufficient reference calls had been recorded for particular species (due to low capture rates), reference calls from other regions were used to supplement the call library. An identification key was developed, based on the frequency and shape characteristics of the recorded pulses, and used to standardise the identification process, and to enable verification of identified calls using a sample of reference calls in a blind test.

Appendix 2 broad habitat types

Shrubland (SH) — areas of medium to tall shrubland dominated by species of *Dodonaea*, *Acacia* and *Eremophila*.

Low Open Chenopod Shrubland (OCS) — low shrubland dominated by species of *Maireana*, *Atriplex*, and *Rhagodia*.

Low Canegrass Shrubland (LCS) — sand ridges, adjacent to lakes, dominated by (often dense) Sandhill Canegrass *Zygochloa paradoxa*

Black Box Woodland (BB) — woodland dominated by Black Box *Eucalyptus largiflorens*. Less frequently inundated areas than those supporting Floodplain Woodland (Red Gum). The understorey supports a sparse to dense cover of various grasses, herbs and sedges. Patches of Lignum may also be present.

Red Gum Forest/Woodland (RG) — woodland dominated by River Red Gums *E. camaldulensis*. Periodically inundated but not to the extent where the trees have been drowned. The understorey varies from sparse to dense cover of various grasses, herbs and sedges when dry, and the ground is generally covered by dense leaf litter and other coarse woody debris.

Lignum Swamp (LS) — regularly flooded depressions with an open to dense cover of Lignum *M. florulenta*. A variety of other herbs, grasses and sedges may also be present.

Shallow Freshwater Marsh (SFM) — regularly flooded depressions that support free floating and emergent attached aquatic species when water is present. When these areas dry out they become Dry Lake-bed Herbfield/Grassland/Sedgeland. This habitat type also includes areas of emergent vegetation associated with the larger lakes (generally along their perimeter).

Dry Lake-bed Herbfield/Grassland/Sedgeland (DLH) — the dried-out areas of exposed lake-bed. Soon after the water recedes, herbs, grasses or sedges cover these areas.

Open Water (OW) — expanses of deep/shallow water associated with the large lakes and narrow channels of open water between lakes. Remnant dead trees may occur at moderate to high densities. Banks would be fringed with patches of native vegetation depending on the water level, including live or dead trees, generally River Red Gums.